PHYS 480/580: Introduction to Plasma Physics – Fall 2020

Course Instructor: Frank Toffoletto
Instructor Coordinates: toffo@rice.edu; 713-348-3641; Office: HBH 362
Class Time / Location: Tues/Thursday: 09:40AM - 11:00AM

Overall course objectives and expected learning outcomes

By the end of this course you should be able to have a working understanding of the elements of Plasma Physics on topics include including: Basic plasma properties; Motion of charged particles in magnetic field; Plasma waves; Magnetohydrodynamic and kinetic representation of plasmas.

Course Description

Plasma physics is an important subject for a large number of research areas, including space plasma physics, solar physics, astrophysics, controlled fusion research, high-power laser physics, plasma processing, and many areas of experimental physics. The primary learning outcome for this course is for the students to learn the basic principles and main equations of plasma physics, at an introductory level, with emphasis on topics of broad applicability.

A plasma may be generally defined as any statistical collection of mobile charged particles. Thus, statistical physics and electrodynamics provide the fundamental basis for the physics of plasmas. An undergraduate course in classical electrodynamics (such as PHYS 302) is the only prerequisite for the course; relevant aspects of statistical physics and mechanics are reviewed or introduced as needed.

The required text for the course is *Plasma Dynamics* by R. O. Dendy. This book contains a good balance between mathematical formulations and physical principles, it is clearly written, and it uses an appealing logical organization of the subject which provides an excellent framework for a first course in plasma physics. The well-known text *Introduction to Plasma Physics and Controlled Fusion* by F. F. Chen is a recommended text for the course, and in many ways it complements and reinforces material covered in Dendy's book.

The course begins with a description of various types of plasmas and a discussion of some basic plasma parameters, such as the Debye length and the plasma frequency. Following a discussion of charged particle motion in electromagnetic fields, progressively more detailed models of plasmas are presented, starting with a dielectric description of cold plasma and moving on to the magnetohydrodynamic and kinetic descriptions. Additional topics may be added as time allows.

General Information

Course Prerequisite: PHYS 302 Classical Electrodynamics, or equivalent
Credit: 3 semester hours
Classroom: Online
Website: Canvas

Office Hours

In person office hours are by appointment only. Email me to set up an appointment. Remote office hours will be conducted via Zoom.

Textbook

Required: *Plasma Dynamics*, R. O. Dendy, Clarendon Press, Oxford, 1990.
Recommended but not necessary: *Introduction to Plasma Physics and Controlled Fusion*, second edition, F. F. Chen, Plenum Press, 1984.

Homework and Grades

Homework Policy: Students are encouraged to discuss the problems with their classmates and with the instructor, but they must write up their homework solutions *independently*. You must not copy anyone else's solution.

Late Policy: The grade for late homework will be 10% off for each part of a day late up to 50% off.

Honor code: You are welcome to help each other in completing assignments, but all work that you turn in must be your own and will fall under the pledged policy. Any evidence of copying will result in an automatic zero for the assignment for all parties involved and in some cases honor council involvement.

Class Presentation/projects:
For students enrolled in PHYS 480: Students will be asked to make a short presentation to the class on some aspect of plasma physics to be given near the end of the semester. The topic will be chosen by the student and approved by the instructor.

For students enrolled in PHYS 580: Students will be asked to do a substantial computational project, on a topic related to some aspect of plasma physics and present their project to the class at the end of the semester. The topic will be chosen by the student and approved by the instructor.

Grading Weights:

Homework and Assignments: 45%
Midterm Exam: 20%
End of course Exam: 20%
Class Participation: 5%
Class Presentation (480) / Project (580): 10%

Attendance and Participation Policy

- All students who live four or fewer time zones away, are expected to attend every class synchronously via Zoom.
- All students who are living where the time zone is >4 hrs from the central time zone are expected to either attend class synchronously via Zoom or to work out in advance with the instructor a suitable solution for asynchronous attendance.
- Students attending class synchronously via Zoom are expected to arrive to class on time (e.g., within 5 minutes of start time). This is essential because links/docs posted in the Chat window and are only available to students who are present at the time the links are posted. Links will not be reposted to accommodate students who arrive late.
- Students are expected to be actively engaged in the classroom. If you are joining class remotely, please keep your video camera on and microphone muted. Use the [chat, raise hand, unmute, etc.] when you have questions or would like to participate. Students needing an accommodation for using their camera or microphone should contact the instructor at the beginning of the semester to discuss and work out needed adjustments.
- Active engagement is an essential component of the learning process. Participation in online courses includes reading and exercises within online forums and activities during the week in which the class is engaged with the same content. Students are expected to log into the course, monitor course progress, and engage as appropriate for the course several times a session.

Students with Disabilities

Any student with a documented disability needing academic adjustments or accommodations is requested to speak with me during the first two weeks of class. All discussions will remain confidential. Students with disabilities will need to also contact Disability Support Services in the Ley Student Center.

Title IX statement

Rice University cares about your wellbeing and safety. Rice encourages any student who has experienced an incident of harassment, pregnancy discrimination or gender discrimination or relationship, sexual, or other forms interpersonal violence to seek support through The SAFE Office. Students should be aware when seeking support on campus that most employees, including myself, as the instructor/TA, are required by Title IX to disclose all incidents of non-consensual interpersonal behaviors to Title IX professionals on campus who can act to support that student and meet their needs. For more information, please visit safe.rice.edu or email titleixsupport@rice.edu.

Technology

- Students attending remotely must have a working computer with a video camera, speaker and a microphone, and a working internet connection that allows them to be on video. Students should test their equipment before joining class. Undergraduate students should contact the Dean of Undergraduates if they have concerns about meeting this requirement. Graduate students should contact their department.
- If your computer/phone has no webcam/microphone, which are needed to complete some assignments, please let the instructor know as soon as possible and [contact the Dean of Undergraduates if you need to request support via the Access and Opportunity Portal (HTTPS://AOP.RICE.EDU/APPLICATION), contact your

academic department if you are a graduate student, request to borrow one from the Digital Media Commons].

Privacy and Confidentiality

In line with FERPA REQUIREMENTS, recorded classroom discussions involving students will be available only to students officially registered and enrolled in the class. If you have concerns about appearing on these recordings, please contact the instructor ahead of time.

PHYS 480/580 - Course Content – Tentative – Subject to Change

1. Introduction
    - Definition of a plasma
    - Units
    - Classification of plasmas, the *n*-*T* diagram
    - A review of classical electrodynamics and vector calculus
2. Basic Plasma Characteristics
    - The electron plasma frequency
    - The Debye length
    - Electrostatic plasma waves
    - Coulomb collisions
3. Motion of a Charged Particle in Magnetic Fields
    - Constant uniform magnetic field
    - Constant uniform magnetic field with non-magnetic forces
    - Guiding center motion in non-uniform magnetic fields
4. Waves in a Cold Plasma
    - General formulation
    - Waves in a cold unmagnetized plasma
    - The dielectric tensor for a cold magnetized plasma
    - Waves in a cold magnetized plasma
5. Magnetohydrodynamic Description of Plasma
    - What is magnetohydrodynamics?
    - The MHD equations
    - General properties of ideal MHD plasmas
    - MHD equilibrium
    - MHD waves
    - MHD stability
    - MHD shocks
6. Kinetic Description of Plasma
    - The Vlasov equation
    - Connections to fluid theories
    - Vlasov theory of electrostatic plasma waves
    - Landau damping
    - The Fokker-Planck equation and binary Coulomb collisions